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System analysis and processing of parameters of the test bench

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System analysis and processing of parameters of the test bench

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Abstract. The paper deals with the analysis of complex technical objects – test stands of control systems. A method is proposed for evaluating the effectiveness of the test bench based on the parameters obtained using the "standard" and "automated" test stand model. The objective function for calculating the efficiency of test benches based on their parameters and determining the numerical efficiency coefficient of the testing position relative to the typical one is given. The composition of the software for implementing the proposed method is shown.
Keywords: automatic control system, test bench, analysis of the testing process, calculation of the efficiency of the test bench.

1. Introduction

The continuous development of software and hardware complexes of automatic control systems, the complexity of redundancy algorithms to ensure high reliability, growing number of tasks to be solved and parameters controlled in the process of operation in the modern world placed increased requirements on the testing process at all stages of ground-based experimental development of new automatic control systems [1, 2].

The solution to the problem of conducting a full-fledged testing is possible only if all the necessary tools are available, as both simulation and registration equipment, and automation tools. At the same time, simulation and registration equipment determine the functionality that the test stand has, while automation tools largely determine the capabilities in terms of the volume of tests per unit time [3].

Today, there are a large number of technologies that allow automating the testing process, which in turn gives rise to the problem of choosing effective approaches to developing test stands in a tight time frame [4, 5]. The relevant issue is the formalization of choosing effective approaches to optimizing the testing process [6, 7]. In order to solve this problem, it is proposed a method for evaluating the effectiveness of the test stand being developed (upgraded) by comparing it with the base one.

2. General concept of the effectiveness evaluation method

The method for evaluating the effectiveness of the test stands is based on comparing the parameters of the basic development position with the parameters of the automated position being developed (upgraded), which uses various methods and technologies for optimizing the development process [8]. The method allows to evaluate the feasibility of using various tools, methods and technologies to minimize the time spent searching for errors at all stages of the test stand life cycle (from design to standard operation).

The method is based on the models of "basic" and "automated" test positions. Source data (primary information) for evaluating the effectiveness of the test stand is contained in the technical terms (TT), source data (SD) and organizational documents for the development of the control system (CS). Primary information is fed to the inputs of the "basic" and "automated" working position models. Reference information is provided in the model for organizing calculations of parameters of the test position. Periodic updating of reference information allows you to keep the methodology up-to-date over time. Information about the automation technologies used in the designed complex is transmitted to the model of the "automated" test position. At the output of the models, the same sets of position parameters with different quantitative values are formed. They are sent to the input of the efficiency calculation module, which, in accordance with the target function, calculates the efficiency coefficient of the projected position relative to the reference one (figure 1).

The method of evaluating the effectiveness of the test position allows you to evaluate the results of automation by the ratio of the effect expressed in reducing the time of testing and reducing the labor resources involved at the test stage to the cost of developing and operating the test stand. The proposed method uses mathematical models of "standard" and "automated" test stands [9, 10] and is the basis of the methodology for constructing an optimal test stand.

To increase the efficiency of the test stand, it is proposed to automate it by using CAD components "Testing" (technologies and methods of automation):

- software package of centralized management;
- mechanism for Cycling modes;
- system for planning and processing test results;
- test results analysis system;
- universal simulating and recording complex;
- universal configuration file editor;
- ID development system in a form suitable for machine processing;
- reducing the number of process equipment.

Determination of the optimal structure of the test stand (selection of automation tools used in the position) is carried out at the stage of issuing TT for the position using the method of evaluating the effectiveness of the optimal test stand relative to the standard one.

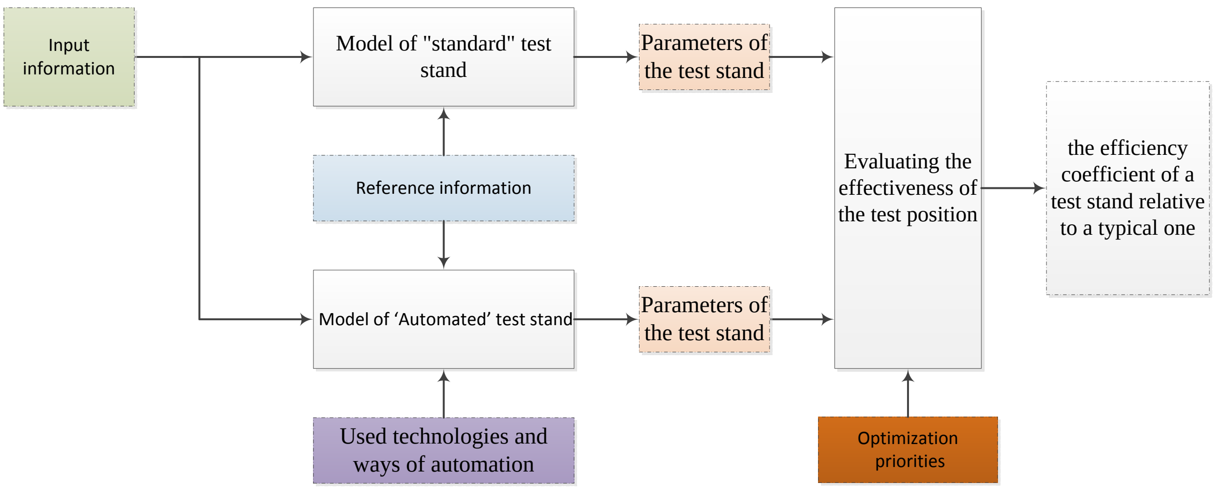

Figure 1. General structure of the test bench performance evaluation method

3. The objective function of the calculation of the efficiency test stand

In General, the parameters of the standard and development positions ($\overrightarrow{W}_{type}, \overrightarrow{W}_{auto}$) are determined by the formulas (1, 2), respectively:

$$\vec{W}_{type} = F_{type}(\vec{A}) \text{ , } with\ \vec{C} = const \quad (1)$$

$$\vec{W}_{auto} = F_{auto}(\vec{A}, \vec{P})\ with\ \vec{C} = const \quad (2)$$

where $\vec{A}$ – is the input information vector, $\vec{P}$ – is the used technologies, $\vec{C}$ – is the reference information, F_{type} and F_{auto} models of typical and automated development positions.

The model of an automated development position is based on a model of a typical position with automation technologies introduced into it (with $\vec{P} = \vec{0}, \vec{W}_{auto} = \vec{W}_{type}$)

The efficiency coefficient of the development position relative to the standard one (K_{effect}) is calculated using the formula (3):

$$K_{effect} = F_k(\vec{W}_{MNP_{auto}}, \vec{W}_{MNP_{type}}, \overrightarrow{PR}) \quad (3)$$

where $\vec{W}_{MNP_{auto}}$, $\vec{W}_{MNP_{type}}$, – vectors of weakly dependent parameters of the automated and typical test stands, respectively, are calculated using the formula (4, 5), $\overrightarrow{PR}$ – vector of weight coefficients (priorities), allows you to set optimization criteria.

$$\vec{W}_{MNP_{auto}} = \vec{W}_{auto} \times \overline{\overline{MNP}} \quad (4)$$

$$\vec{W}_{MNP_{type}} = \vec{W}_{type} \times \overline{\overline{MNP}} \quad (5)$$

where $\overline{\overline{MNP}}$ – matrix for selecting weakly dependent parameters.

The vector of weakly dependent parameters contains (6):

– time to prepare and evaluate test results ($T_{prepare\_eval}$);
– utilization rate of standard equipment (K_e);
– total cost of developing a test stand (S_{cost_dev});
– cost of operating a test stand ($S_{cost\_operate}$).

$$\vec{W}_{MNP} = \left(T_{prepare\_eval}, K_e, S_{cost\_dev}, S_{cost\_operate}\right) \quad (6)$$

The advantage of the developed method is to set up models of test stand for a specific task (projected stand) based on the specified input information, so within the optimization of one test stand, the input information is constant ($\vec{A} = const$).

The main advantage of the efficiency of the assessment method is the ability to determine the quantitative value of the efficiency coefficient of the test stand relative to the standard one. At the same time, it is necessary to note an important feature, which is that it is possible to set priorities for the compared parameters. For example, if you need to minimize the testing time, you need to set a high priority for the first two parameters to be compared, and if the cost of developing and operating a position is not critical, you can lower their priority or exclude them from the effectiveness assessment by setting the priorities for these parameters equal to zero. Optimization of the structure of the automated test stand is performed taking into account the set priorities ($\overrightarrow{PR} = const$).

Based on the formula (7), we obtain the efficiency coefficient of the test stand optimized with the specified priorities relative to the standard one (7):

$$K_{effect} = F_k(\vec{W}_{MNP_{auto}}(\vec{P})), \text{with } \vec{A} = const, \overrightarrow{PR} = const \quad (7)$$

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The optimal set of automation technologies and methods ($\vec{P}_{optim}$) is determined by the maximum value of the efficiency coefficient of the development position relative to the standard one with the specified priorities (8).

$$\max(K_{effect}) = F_{\text{к}}\left(\vec{W}_{MNP_{auto}}(\vec{P})\right), \vec{A} = const, \overline{PR} = const, \vec{P} = \vec{P}_{optim} \tag{8}$$

The time limit for optimizing the structure of a test stand in real conditions is the start time of the stand (T_{create}). Development time of the test stand (T_{dev}) calculated during simulation and depends on the selected automation technologies ($\vec{P}$) (9, 10).

$$T_{dev}(\vec{P}) \leq T_{create} \tag{9}$$

$$T_{dev} = \vec{W}_{auto}(\vec{P}) \times \overrightarrow{FL\_T}^{T} \tag{10}$$

where $\overrightarrow{FL\_T}$ – the vector of time allocations development.

Input information for the module for calculating the efficiency of the test stand, in accordance with the method structure (figure 1), is:

- a set of weakly dependent parameters of a "typical" test stand (MNP_TIP);
- a set of weakly dependent parameters of an "automated" test stand (MNP_AVT);
- a set of priorities for evaluating the effectiveness of a test stand (PR).

A set of weakly dependent parameters is generally denoted MNP.

Weakly dependent parameters are divided into two categories:

- parameters which should be minimized ($MNP_{min}, MNP\_TIP_{min}, MNP\_AVT_{min}$);
- the settings that needed to maximize (MNP_{max},MNP_TIP_{max},MNP_AVT_{max}).

Function for calculating the efficiency coefficient of a test stand relative to a typical one (K_{effect}) is given in formula (11).

$$K_{effect} = \sum_{i=1}^{N_{MNT_{min}}} \frac{MNP\_TIP_{min_i}}{MNP\_AVT_{min_i}} * K\left(MNP_{min_i}\right) + \sum_{j=1}^{N_{MNT_{max}}} \frac{MNP\_AVT_{max_j}}{MNP\_TIP_{max_j}} * K\left(MNP_{max_j}\right) \tag{11}$$

where $N_{MNT_{min}}$ – the number of weakly dependent parameters that need to be minimized, $N_{MNT_{max}}$ – number of weakly dependent parameters to maximize, $K\left(MNP_{min_i}\right), K\left(MNP_{max_i}\right)$ – the value of the weight coefficients for the corresponding weakly dependent parameters.

Weight coefficients are calculated as the ratio of the priority of one MNP to the sum of all priorities according to the formula (12).

$$K(MNP_x) = \frac{PR(MNP_x)}{\sum_{l=1}^{N_{PR}} PR_l} \tag{12}$$

where $PR(MNP_x)$ – priority value for a single weakly dependent parameter, MNP_x – one weakly dependent parameter (take the values MNP_{min_i} or MNP_{max_j}).

The objective function for calculating the efficiency coefficient of a test stand relative to a typical one is generally given in formula (13).

$$K_{effect} = \sum_{i=1}^{N_{MNT_{min}}} \frac{MNP\_TIP_{min_i}}{MNP\_AVT_{min_i}} * \frac{PR\left(MNP_{min_i}\right)}{\sum_{l=1}^{N_{PR}} PR_l} + \sum_{j=1}^{N_{MNT_{max}}} \frac{MNP\_AVT_{max_i}}{MNP\_TIP_{max_i}} * \frac{PR\left(MNP_{max_j}\right)}{\sum_{l=1}^{N_{PR}} PR_l} \tag{13}$$

4. Implementation

Software "System for calculating the efficiency of the test stand" has been developed for modeling test stands and selecting optimal technologies and optimization methods (figure 2).

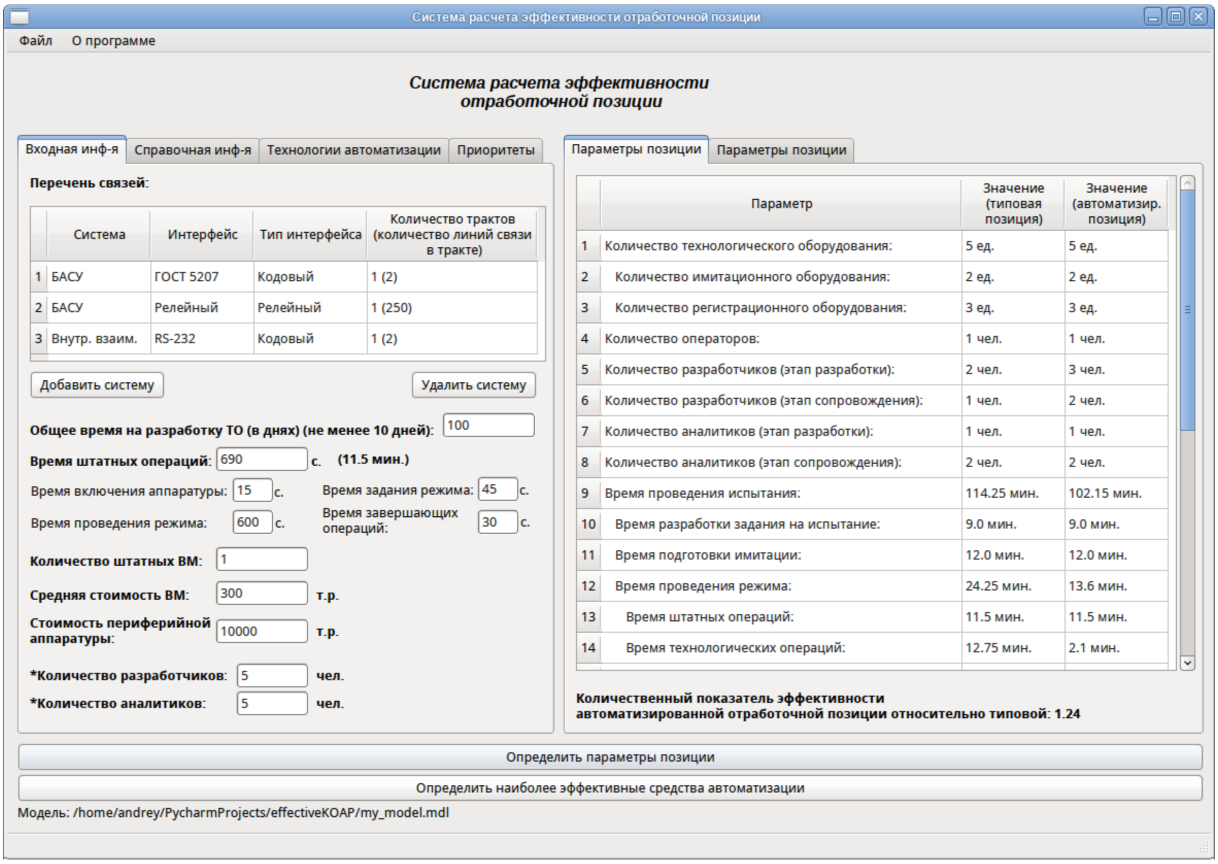

Figure 2. User interface of the software «System for calculating the efficiency of the test stand»

The software "Systems for calculating the effectiveness of the test stand" is developed on the basis of the proposed method for evaluating the effectiveness of the test stand (Python programming language) and includes:

1. modeling module (implements mathematical models of a typical and automated test stand);
2. module for calculating the efficiency coefficient of the test bench relative to the standard;
3. module for determining the optimal set of technologies and optimization methods;
4. the user interface subsystem;
5. model loading/saving subsystem;
6. the subsystem generate the results.

Modules 1 and 2 implement functions in accordance with the structure of the methodology for evaluating the effectiveness of the test stand, while module 1 is unified and allows you to calculate both the parameters of a typical stand and the optimized one when specifying the array of optimization technologies used.

Module 3 generates all acceptable sets of optimization technologies, and determines the efficiency coefficient of the test bench relative to the standard one in accordance with the methodology implemented by modules 1 and 2 for each set, while the current maximum value of the coefficient and the set of optimization tools for which it was calculated are saved. When all possible options are considered, the module outputs the optimal set of optimization technologies and tools with the maximum efficiency coefficient. It is important to note that when calculating the stand parameters, the number of specialists (developers and analysts) at the stand development stage is taken into account (if the limit is set).

Subsystem 4-6 to implement the standard functionality of the software. Subsystem 4 provides the user interface (figure 2). Subsystem 5 saves and loads models. The model is described by sets of input and reference information, as well as information about applied technologies and optimization methods. A specialized file of its own structure is used for saving. Subsystem 6 generates results and displays them on the screen, in the corresponding components of the user interface.

The software "System for calculating the effectiveness of the test bench" has the following functions:

– calculation of parameters of optimized and typical test stands based on the specified input and reference information and selected optimization technologies (methods) ;
– calculation of the efficiency coefficient of the optimized stand relative to the typical one for the selected set of optimization tools;
– determination of the optimal set of test bench optimization tools for the specified conditions (time of stand launch and number of specialists);
– calculation of the development time of technological equipment for an optimized test stand with a specified number of specialists;
– setting priorities for optimization of the test bench when calculating the efficiency coefficient of the test bench relative to the standard one.

5. Conclusion

The proposed method for evaluating the effectiveness of the test bench allows to evaluate the feasibility and ability of using various tools, methods and technologies to minimize the time of error detection at all stages of the life cycle (from design to standard operation).

In this work, support systems are developed for making decisions on choosing the best version of the test stand, created specialized software for performing calculations based on the method of evaluating the effectiveness of the test stand, and developed a method for determining the optimal version of the test stand.

Systems and software complexes developed in accordance with the solutions discussed in this paper have certificates of state registration.

The developed method can be applied to test stands of control systems for various purposes, in particular to control systems for strategic and space purposes.

References

[1] Mikrin B A 2003 *On-Board spacecraft control systems and design of their software* (Moscow: Bauman Moscow state technical University) pp 94-128

[2] Dudin N V, Khokhryakov V A and Shchepochkin I N 2013 Software development process of the FSUE scientific and production Association of automation named after academician N. A. Semikhatov *Actual problems of rocket and space technology "III Kozlov Readings"* (Samara: FSUE "gnprcc "TsSKB-Progress") pp 218-221

[3] Gorkun E V, Klyuchnikov A V, Kuznetsov A V, Kuzminykh, Lysykh A V and Timoshchenko A G 2012 Development of an automated system for testing multi-channel power Supplies *Collection of reports of the youth scientific and technical conference-2012, dedicated to the 65th anniversary of JSC Makeyev GRC* vol 2 (Miass: JSC "GRC Makeeva") pp 40-43

[4] Severov A, Ushakov V, Govorenko G and Teterin D 2013 Automated stand for testing control systems of rocket and space launch complexes *J. Modern automation technologies* vol 1 (Moscow: STA Press) pp 70-74

[5] Dudin N V 2013 Model of temporary control LAWS *Rocket and space technology*. *Control systems of rocket complexes*, issue 1 (Yekaterinburg: Federal state unitary enterprise "NPO Avtomatiki im. Academician N. A. Semikhatov") pp 2-5

Journal of Physics: Conference Series **1694** (2020) 012002 doi:10.1088/1742-6596/1694/1/012002

[6] Karasev A A and Chuprinsky I I 2013 On the development of methods for testing onboard equipment as part of an automatic spacecraft *Actual problems of rocket and space technology "III Kozlov Readings"* (Samara: FSUE "gnprcc "TsSKB-Progress") pp 324-326
[7] Tovpeko A V 2013 Key quality indicators of space telemetry processing and analysis systems *Actual problems of rocket and space technology "III Kozlov Readings"* (Samara: FSUE "gnprcc "TsSKB-Progress") pp 605-606
[8] Achkasov V N, Antimirov V M, Mezhov V E and Zolnikov V K 2005 *Development of automation tools for designing specialized microchips for dual-purpose control computer systems* (Voronezh: Voronezh state University) pp 120-143
[9] Zhuravlev A V, Shashmurin I V and Petukhov V I 2014 Mathematical model of the typical development position of the aircraft control system equipment *Materials of the ninth interregional industry scientific and technical conference* (Yekaterinburg: JSC "OKB "Novator" named after L. V. Lyulev") pp 136-138
[10] Zhuravlev A V and Shashmurin I V 2014 Mathematical model of the "automated" development position of ship information and control systems *State, problems and prospects of creating ship information and control systems* (Moscow: JSC "Concern "Marines-Agat") pp 30-35